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STAND IMPROVEMENT OF NORTHERN HARDWOODS IN RELATION TO DISEASES IN THE NORTHEAST

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INTRODUCTION

The purpose of this paper is to call attention to certain tree diseases which hamper the growing of profitable crops of northern hardwoods in the Northeast, and to show how timber stand improvement operations can be directed toward reducing the losses caused by the tree diseases. The species included in the term "northern hardwoods" as used here are: sweet birch (*Betula lenta* L.), paper birch (*Betula papyrifera* Marsh.), yellow birch (*Betula lutea* Michx. f.), red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), American beech (*Fagus grandifolia* Ehrh.), black ash (*Fraxinus nigra* Marsh.), American ash (*Fraxinus americana* L.), American basswood (*Tilia americana* L.), black cherry (*Prunus serotina* Ehrh.), quaking aspen (*Populus tremuloides* Michx.), and bigtooth aspen (*Populus grandidentata* Michx.)

The northern hardwoods are important species in a number of forest cover types of the Northeast as established by the Society of American Foresters. 1/ Some of the important cover types for the northern hardwoods are: sugar maple-beech-yellow birch, sugar maple-basswood, sugar maple, yellow birch, yellow birch-red spruce, and red spruce-sugar maple-beech. These species also occur frequently as minor elements in a number of other coniferous types.

Each of these types occurs on sites of varying quality ranging from highly productive to submarginal for that type. Stand improvement work is most effective on the more productive areas where an investment in time and money can be expected to bring adequate returns and where disease attacks are not so heavy as to interfere with the future development of the stand. Stand improvement for sawtimber is rarely justified on sites deteriorated by intense or repeated fires, in poorly drained or frosty situations, those near the upper elevations for the tree species, or those on warm slopes at the southern edge of the natural range of the species. Under such conditions cankers and decay are very apt to become chronic and destructive and trees even of the best species are short-lived and poorly formed, and make slow growth. However, other forest uses than sawtimber production may justify stand improvement measures on poor sites.

Native diseases are usually unevenly distributed through the forest and certain stands may be heavily attacked while neighboring ones are relatively free. In a given stand the prevalence of tree diseases and the probable future commercial value of the various tree species should be used as a guide to determine which should be favored in stand improvement and harvest cutting practice.

Most northern hardwood species sprout readily following fire or cutting. These sprouts grow rapidly and often form multiple-stemmed clumps which interfere with the establishment of more desirable seedlings. Sprouts

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1/ Forest cover types of the eastern United States. Jour. Forestry 30:451-498. 1932.

as a rule produce inferior sawtimber because of poor form or butt rot which originates in the parent stump or in dead or cut companion stems. Many stands are made up largely of sprouts or have scattered sprout clumps which should be discriminated against in favor of the more promising seedlings.

I. STAND IMPROVEMENT IN NORTHERN HARDWOODS

PURPOSES AND METHODS OF STAND IMPROVEMENT

Briefly stated the broad purpose of stand improvement is the production of good quality and volume of sawtimber in the shortest possible time. This is accomplished in a given stand by the selection of healthy, well-formed trees of desirable species for the future crop, and by encouraging these to grow vigorously by reducing competition from less desirable neighbors. The emphasis upon the selection of healthy trees makes it imperative that foresters and others engaged in stand improvement recognize certain types of tree disease.

One method of stand improvement attempts to accomplish its purpose by the general favoring of all trees having the greatest potential future value. By the crop tree method disease-free trees are selected at intervals depending upon the age and type of stand and these trees are freed from injurious competition. Regardless of the method used, stand improvement should increase the percentage of disease-free trees of desirable species left to grow and produce good quality timber.

Trees of seedling or seedling sprout origin have more potential value for sawtimber than stump sprouts and should be favored for crop trees wherever possible. Reduction of the number of stump sprouts in a stand should be one aim of improvement work.

GENERAL RECOMMENDATIONS FOR STAND IMPROVEMENT

Foresters and others doing improvement work in hardwood stands are cautioned not to overlook the silvicultural phases of stand improvement when confronted with disease control problems. In stands where disease is at a minimum silvicultural recommendations can be followed with little interference but in stands where many of the trees are already diseased more emphasis may need to be placed on disease control than upon silviculture. Ordinarily good silvicultural practices are also good disease control practices, and where the two are in conflict a compromise must be effected.

Hardwoods growing on good sites, unless the existing stand has been subjected to fire, careless logging, or other abuse, can be expected to produce timber with a minimum interference from disease. Hardwood stands on poor sites often are inherently susceptible to canker and decay and improvement work cannot be expected to remedy the condition. Control of diseases of this type is ordinarily simpler and more effective on good sites than on poor and it is recommended that stands on good sites be given priority in any improvement program.

Young stands contain more potential crop trees than middle-aged or old stands provided the species composition is desirable, and with proper handling these crop trees can be grown on a long rotation and at the

proper rate of growth to provide the best timber. Older stands that are already rot-defective must be harvested as early as practicable. Therefore it is recommended that more attention be paid to young stands than to older stands that are already defective at the time the improvement program is started.

Stand improvement, when well done, should not only decrease the amount of disease among the desirable trees in the stand, but by reserving more vigorous trees decrease the number of future infections by canker and decay-causing fungi. On the other hand, carelessness on the part of those doing stand improvement may result in trunk, base and top injuries to potential crop trees, and thus increase the opportunity for rot infections. Improper treatment of sprouts in particular may lead to an increase in the amount of decay. Stand improvement in northern hardwoods should not result in an excessive opening of the stand since this condition often causes sunscald in certain species and predisposes others to insect attacks. Widespread dying of birch and beech is also associated with excessive opening of the stands.

Specific control measures for canker and rot diseases are considered in the following sections. Recommendations for treating sprouts are also given separately.

Control of Cankers

Cankered trees are undesirable elements in the stand because they are frequently short-lived and if they do reach timber size their value is materially lessened by the defective parts. At best they must be considered permanently defective trees with a low present value and little potential future promise. Cankers are present in practically every northern hardwood stand and eradication is economically impossible. Some stands may be lightly cankered while adjacent ones may be heavily infected. This may be accounted for in part by a difference in sites; in general, stands on poor sites are more apt to be badly cankered than those on good ones. Tree species also vary greatly in the amount of cankering in different stands. This may be due to individual variation of the tree, of the canker fungus, or to the degree of adaptation of the tree to its site. The same site may be favorable to one species and unfavorable to another, leading to a corresponding difference in the degree of cankering. The least cankered desirable species is the one to be favored, and the heavily cankered species should be discriminated against.

The majority of trunk canker infections originate in the early life of the stand. By the time the stand is 25 years old most canker infections have already taken place. Canker-free crop trees selected at this age can be expected to remain healthy.

In actual practice, canker-free trees of desirable species should be favored as potential crop trees. In case the choice must be made between a lightly cankered tree of a desirable species and a canker-free weed tree the former should be selected. In general, the larger

cankered trees should be felled in stand-improvement operations unless there are good silvicultural reasons for retaining them. Wherever possible it is desirable to utilize the cankered sections for firewood.

If a stand on a poor site is heavily cankered, stand improvement is usually not justified because the conditions so favor cankering that succeeding hardwood stands cannot be expected to be any better.

Control of Heartrots

As far as is known the important rot diseases of northern hardwoods are of native origin. Rot-infected trees have little promise for timber and it is desirable to remove all rotted trees not needed on silvicultural grounds. Young stands are usually relatively free from rot and the number of expected rot infections increases with age. Older stands on good sites that have been subjected to fires, or to partial cuttings in which the best trees have been removed, are often heavily infected and it is difficult to find properly spaced, potential, rot-free, crop trees. Hardwood stands on poor sites are often very rot-defective. Such defective stands ordinarily do not warrant improvement and such treatment as may be undertaken should be designed to open the present stand sufficiently to encourage seedlings. Control of heartrots in stand improvement is usually limited to (1) selecting rot-free crop trees, (2) avoiding rot by preventing wounds, and (3) reducing inoculum.

1. Selecting rot-free crop trees. This is relatively simple in young stands 15-25 years old, since ordinarily few rot infections are present at this age. Trees with existing butt or trunk wounds should be discriminated against, especially if these wounds are large and are healing slowly. Such wounds if not rot-infected at the time the improvement work is done may become so before they heal. Young trees with top wounds caused by glaze or wind ordinarily do not become seriously rot-infected and trees with such injuries need not be discriminated against on the basis of probable future decay. Conks of heart-rotting fungi on a tree are positive evidence of rot within. However, these are usually found only in older stands. Abnormally swollen branch wounds and rot cankers are also signs of decay within the tree. Trees with known rot infections should be discriminated against since they have little or no future promise for timber.

2. Avoiding rot by preventing wounds. Wounds of several kinds are associated with stand improvement and careless work may increase the amount of future rot in a stand by providing suitable entrance courts for wood-rotting fungi. Carelessness in felling undesirable trees and in removing cordwood from the stand frequently causes logging injuries which may result in extensive rot. Defective trees not directly affecting crop trees, but which may break over in a few years, should be cut. Ordinarily these can be felled with minimum damage, but if left to be windthrown may injure or destroy promising crop trees. Careless ax work, especially in treating sprouts, often causes wounds which heal slowly and favor decay. The burning of

brush piles in the stand may cause unsuspected heat injuries to nearby trees. Sunscald and borer attacks have been known to follow excessive opening of maple and birch stands. Effective stand improvement must not only guard against the formation of mechanical wounds on the crop trees but against wounds caused by insects, sun, glaze, and wind, resulting from changed conditions within the stand.

3. Reducing inoculum. This is ordinarily accomplished by the felling of trees bearing conks of heart-rotting fungi. These trees should be utilized for firewood wherever possible. However the removal of all conk-bearing trees cannot be justified and only those trees having conks of fungus species known to attack the favored tree species should be discriminated against purely for reducing the amount of inoculum (See Table 1.). Care must be taken to distinguish these from strictly saprophytic fungi, or heart-rotters confined to undesirable or weed species.

Maples and beech rotted by *Polyporus glomeratus* (Page 21) and birches rotted by *Poria obliqua* (Page 21) often remain alive indefinitely. Spore production takes place only after the infected trees are dead, and living infected trees bearing sterile conks are safe associates for crop trees and may be left in the stand if they promise to persist for some time and are needed to maintain the canopy.

ESTIMATING DISEASE CULL IN MERCHANTABLE NORTHERN HARDWOODS

In cruising timber, or in marking trees for felling, it is desirable to know how much cull should be deducted in trees bearing conks. This varies with the tree species and the kind of rot, and also with the length of time the rot has been present in the tree. Table 2 gives average cull for the common trunk-rotting fungi found in the more important tree species.

THE SPROUT PROBLEM IN NORTHERN HARDWOODS

Sprouts arise from buds which are found abundantly at the base of the tree near the root collar and less abundantly farther up the trunk. When the tree is cut, or the part above ground is girdled or killed by fire, some of these buds start to grow and eventually produce sprouts. The number of sprouts in a clump is an indication of the size of the parent stump because the larger the stump the more opportunity for buds to develop and continue growth. Sprouts from stumps two inches or less in diameter are commonly referred to as seedling sprouts. Stumps of this size usually have but one or two sprouts and these have the same potential value as seedlings for sawtimber. Those from larger stumps are called stump sprouts. Stump sprouts, unless treated at an early age, usually produce only inferior timber or cordwood.

TABLE I. DISTRIBUTION OF CANKER AND ROT DISEASES OF NORTHERN HARDWOODS IN RELATION TO SPECIES AND AGES OF TREES.

Disease	ash	aspen	basswood	beech	paper birch	sweet birch	yellow birch	black cherry	red maple	sugar maple	Age of trees attacked: 1-25 yrs.	26-50 yrs.	over 50 yrs.
Cankers:													
Eutypella	-	-	-	-	-	-	-	-	O2/	C3/	+	-	-
Hypoxylon blakei	-	-	-	-	-	-	-	-	O	O	+	-	-
" *pruinatum*	-	C	-	-	-	-	-	-	-	-	-	+	-
Nectria	R4/	O	C	O	C	C	C	O	C	C	+	-	-
Rots:													
Armillaria mellea	O	-	O	C	O	-	-	O	C	C	-	-	+
Daedalea unicolor	-	-	-	-	O	-	O	-	C	C	-	+	-
Fomes applanatus	R	O	R	C	R	R	R	R	C	C	-	-	+
" *connatus*	-	-	-	-	-	-	-	-	C	C	-	-	+
" *fomentarius*	-	-	-	C	O	O	C	-	O	O	-	-	+
" *fraxinophilus*	O	-	-	-	-	-	-	-	-	-	-	-	+
" *igniarius*	R	C	R	C	O	O	C	R	C	O	-	+	+
" *igniarius* var. *laevigatus*	-	-	-	-	R	-	C	-	R	R	-	-	+
" *pinicola*	-	-	-	R	-	-	R	C	-	-	-	+	+
Hydnum erinaceus	-	-	-	O	-	-	-	-	-	-	-	-	+
" *septentrionale*	-	-	-	O	-	-	-	-	-	O	-	-	+
Polyporus glomeratus	-	-	-	O	-	-	-	-	C	C	-	-	+
" *sulphureus*	R	-	-	-	-	-	-	O	-	O	-	-	+
Poria obliqua	-	-	-	-	C	C	C	-	-	-	-	+	+
Ustulina vulgaris	R	-	R	C	R	-	-	-	C	C	-	-	+

2/ O = Occasional   3/ C = Common   4/ R = Rare

TABLE II. AVERAGE CULL TO BE EXPECTED IN MERCHANTABLE NORTHERN HARDWOODS BEARING CONKS OF HEART-ROTTING FUNGI

Fungus Species	aspen	beech	paper birch	yellow birch	black cherry	red maple	sugar maple	Part most frequently affected
Fomes applanatus	-	4-6 5/	-	-	-	4-6	4-6	butt
Fomes connatus	-	-	-	-	-	3	3	trunk
Fomes igniarius single conk	6	8	10	8	-	total	8	trunk & butt
multiple conks	total	total	total	total	-	total	-	
Fomes pinicola	-	-	-	-	3-4	-	-	trunk
Polyporus glomeratus single canker	-	4-6	-	-	-	4-6	3-4	trunk
multiple cankers	-	total	-	-	-	total	-	
Poria obliqua single sterile conk	-	-	12	8	-	-	-	trunk
multiple sterile conks	-	-	total	total	-	-	-	
Ustulina vulgaris	-	4-6	-	-	-	4-6	3-4	butt

5/ Linear feet of cull above and below conks

Decay from the parent stump

Shortly after a tree is cut decay starts to develop in the exposed wood of the stump. Under certain conditions in some species, especially oaks, this decay may spread readily to the sprouts. However, direct decay transmission from the parent stump to the sprouts occurs infrequently in northern hardwoods. This is due to the rapidity with which stumps of these species decay, a tendency for sprouts to originate low on the stump, and to a lack of heartwood in some species. Stumps of sugar maple, red maple, ash, basswood, and white birch, regardless of size, do not have durable heartwood and are quickly decayed. Sugar maple stumps over 6 inches in diameter are occasionally infected by Ustulina vulgaris, which is capable of attacking the living sprouts. In most stands such infected stumps are usually too few to be important in stand improvement. Sugar maple, basswood, and white birch do not form heartwood until quite old and sprouts even to a considerable age have only sapwood, which is resistant to most infections originating in the stump. Discolorations of the wood, however, may occur in sprouts of these species at the point where they make contact with the parent stump and may extend some distance up the trunk. Red maple and ash form heartwood relatively early but the stumps are usually decayed by fungi not capable of attacking the living sprout. Black cherry has a durable heartwood which decays slowly. In 6 - 10 years the sprouts form heartwood which connects with heartwood in the stump. Decay transmission from the stump does take place, but black cherry sprouts on favorable sites grow rapidly and ordinarily will produce sawlogs before butt rot results in serious loss.

Armillaria mellea frequently becomes established in sprouts through dead roots or the parent stump. The rot is not extensive but sugar maple and ash sprouts, especially those from large stumps, are occasionally weakened enough at the base so that they are liable to windthrow.

Decay from companion stubs

Many sprout clumps contain more stems than can live to maturity. The sprouts that are favorably placed in relation to the roots continue growth while the others die or persist as suppressed or intermediate stems. If these weak stems die before they are over 2 or 3 inches in diameter little decay hazard results even when such stems have fused with the still living sprouts. Stems of this size do not contain heartwood and are decayed by saprophytic fungi. After a stem is more than 3 inches in diameter at the base, it usually fuses more or less with other sprouts, resulting in a connection which may extend several feet above the ground. These larger stems may also form heartwood in some species, and mature wood in others, causing a considerable decay hazard if they are cut or die naturally. The decay hazard will increase with the size of the cut, or of the dead stem, and with the degree of fusion or engulfment by the living sprouts.

In northern hardwoods under 40 years of age little butt rot traceable to dead companion stubs has been found. However, examination of 226

sugar maple sprouts from 50 to 70 years old, each with one dead stub, disclosed that approximately 65 percent had butt rot and that nearly three-quarters of this rot was traceable to the dead stub. These stubs were mostly over 3 inches in diameter and had been engulfed by the living sprout, forming connections from 1 to 3 feet above the ground. Rot usually extended only a short distance above the connection or was limited to the base of the stub, but since these sprouts still had from 30 to 40 years to grow before making sawtimber, such rot had ample time to cause serious loss. Field examination of red maple, black cherry and paper birch also indicates that rot entering through dead companion stubs may cause serious loss depending upon the age of stand and size of the dead stubs.

Recommendations for stand improvement in sprouts

Seedlings or seedling sprouts should be favored above stump sprouts at all times. Attempts to treat stump sprouts for sawtimber should be made only if stems of more desirable origin cannot be found.

1. Young stands 15-25 years old. Stand improvement in sprouts can best be done in stands 15-25 years old because: (1) There are many stems from which to select well-spaced potential crop trees; (2) sprouts of this age have not fused extensively at the base, do not contain heartwood, and unwanted stems can be removed with the least decay hazard; and (3) the unwanted stems are small and the cost of removal is correspondingly low.

   In practice:

   (1) Crop trees should be selected from clumps of not more than four sprouts. (Fig. 1, A-D)

   (2) The most promising sprout should be retained and the unwanted ones removed.

   (3) If an unwanted stem has a low connection with the favored one it may be cut so as to leave a short stub.

   (4) If an unwanted stem has a high connection, a flush cut or a cut as nearly flush as possible should be made. However, a sprout should not be considered a good risk if the removal of an unwanted stem causes a wound larger than 3 inches in diameter.

   (5) Care should be taken not to injure the favored sprout.

2. Stands over 25 years old. As sprouts grow older, effective stand improvement becomes more difficult and results are correspondingly less satisfactory. Sprouts in the same clump that are of equal size and vigor have like chances of reaching merchantability, and removal of one stem is not likely to stimulate markedly the growth of the others. Regardless of the height of the connection between sprouts they should be left untouched, or the entire clump removed, since

Figure 1. Sugar Maple Sprouts 15 to 25 Years Old

A. Because of the low connection, one of this group of 3-inch sprouts is a potential crop tree, provided the other three are removed.

B. Selection of a satisfactory crop tree from this clump is precluded by high unions and too numerous sprouts.

C. The larger stem is a potential crop tree provided its low union twin is removed promptly to prevent it later on from becoming engulfed, dying and transmitting rot to the main stem.

D. Decay hazard is low where one stem of high union twins can be removed by a flush cut less than 3 inches in diameter; otherwise such trees are poor risks for sawtimber.

their potential value forsawtimber cannot be improved by any operation upon the clump.

If the sprouts in a clump are unequal in size and vigor, the potential value of the most promising one for sawtimber will depend upon (1) the absence of dead companion stubs larger than 3 inches in diameter or other evidence that the promising stem is not already decayed or soon may be, and (2) the decay hazard that will result if the surplus companion sprouts are removed.

Improvement work upon the clump cannot be justified if decay is already established in the best-formed sprout.

The removal of an unwanted companion sprout will result in a low decay hazard to the favored sprout, regardless of the height of the connection, if the resulting wound is made flush and is not larger than 3 inches in diameter. The removal of stems resulting in larger wounds will increase the decay hazard in proportion to the size and number of the wounds and the height of the wounds on the trunk. A sprout should not be considered a good risk as a potential crop tree if the wound resulting from the removal of a companion sprout is over 3 inches in diameter.

II. DISEASES OF NORTHERN HARDWOODS

NATURE OF TREE DISEASE

Forest tree disease for the practical forester is some abnormal and often deteriorated condition of living trees. The visible signs or symptoms may be a sudden slowing up in growth, yellowing and shedding of leaves, dead twigs or branches, decay in the trunk, cankers on trunks or branches, conks of various shapes on the larger woody parts, irregular swellings of the trunk with punky interior, and death of entire trees. The most serious diseases in the northern hardwood forest are caused by various native wood-inhabiting fungi. There are some that are caused by poor soil conditions and adverse climatic conditions. Injuries by various animals (especially insects) also often cause the death of trees but are not considered here.

The Part Played by Fungi

Fungi are living plants which are unable to build up their necessary nutrients as do the green-leaved trees. They can only break down organic substances already made, and their action in wood is usually destructive. They vary greatly in their nutritive requirements and in the way they attack trees in the struggle to get their food materials. Some can thrive only in the dead heartwood of trees; others thrive only in dead sapwood next to large wounds; still others may, after getting well established in the heartwood, kill adjacent living sapwood and gradually extend outwards until the standing tree is completely dead or breaks over.

The native fungous diseases do not threaten extermination of tree species but they commonly are widely scattered through the forest. They can spread to healthy trees, if certain types of injuries are present through which they can enter and establish themselves within the outer protective bark. Naturally, the larger the injury and the longer it remains unhealed, the more chance there is for infection by one of the numerous canker and decay fungi. Branches from the trunk of a tree originate at the center of the trunk, and breakage or death of larger branches opens a direct pathway for wood-decaying fungi to enter and follow the branch wood to the center of the trunk. This is why breakage by heavy windstorms, ice and snow and by carelessly felled trees in various types of partial cutting is so serious to most trees reserved for a long-term rotation.

Injuries that favor damaging cankers and decay are: fire scars, ax wounds, blazes exposing the wood, logging injuries such as basal bruises or patches of bark scraped off in hauling logs (the heavier the equipment used the more damage is likely to be caused), increment boring especially in birches and maples, old branch stubs or knot holes and pruning wounds more than $2\frac{1}{2}$ inches across. Porcupines, rodents, and insects, especially borers, sometimes do extensive damage. Extremes in climatic conditions result in frost cracks, sunscald, and drought injuries.

Inorganic Causes of Disease

There are serious forest diseases that are caused by adverse conditions of the soil or climate. The foréster recognizes many of them as chronic troubles reflected in poor, subnormal growth or in actual death of certain species. He says "the site is not suitable." Areas burned over by hot or repeated fires are examples where poor soil conditions are most frequently encountered. Some of the adverse climatic conditions are drought, recurrent frosts, high winds, and too hot and dry exposures. Slow growth at higher elevations is probably more often due to adverse climatic than to soil conditions.

At higher elevations or in more northern localities, hardwoods are susceptible to severe injury from opening stands too drastically. The resultant abnormally high temperatures and dry soil surface cause leaf rolling, tip dying, trunk scorch, and even death in extreme cases. The reserved trees must be protected from sun in the hottest part of the day and the shade on the ground be continuous enough so that no one spot is exposed to full sunlight more than 2 or 3 hours.

The character of the forest stand itself has a marked influence on disease within it, especially in the sapling or small pole stage of growth. Youthful, fully stocked stands sometimes become so overcrowded that growth decreases sharply because of intense competition for crown space and sometimes for nutrients of the soil. This may lead to attacks by fungi which cannot infect healthy, vigorously growing trees. Thinning before there is any marked signs of stagnation is desirable.

CANKERS

Canker diseases are so prevalent and important in the northern hardwoods that they will be considered here as a separate group. A canker is an area on a tree trunk or branch where the bark and outer layers of wood have been killed, usually by a fungus. Some cankers are annual and are caused by fungi which are active but one season, after which the wound begins to heal, usually without heavy callus formation at the margins. Other cankers are perennial and are the result of a struggle between the tree and the canker fungus, each with alternating periods of activity. This commonly produces deeply pitted or target cankers with prominent callus edges. A canker may girdle the part where it is located or may remain small enough not to girdle it. Sunscald or mechanical injuries on an exposed trunk sometimes cause cankerlike wounds.

Nectria canker

Nectria canker is the most common and generally distributed disease of northern hardwoods in the Northeast. All species may be attacked, but with varying intensity. The birches and maples are most frequently

cankered; the former are often killed. American ash and black cherry are rarely attacked. Sometimes one species in a stand is heavily attacked while the others are cankered only occasionally. Severe cankering often occurs on poor hardwood sites, especially old burns.

Damaging cankers usually are located on the main trunk (Fig. 2, A, B, and C). There are all gradations of canker from the open target type to completely bark-covered depressed or flattened ones which are often found on yellow and paper birch.

Infection takes place through small wounds in the outer corky bark. Cracks made by sharp bending of branches loaded with snow or ice seem to be especially favorable for infection by the fungus. Many Nectria cankers bear traces of dead lateral branches at the center, indicating that the infection probably occurred at or near their junction with the trunk.

The fruiting bodies are reddish brown and round, about the size of a pinhead (Fig. 2, D). They develop on the outer edges of the dead bark or on exposed wood next to the callus.

Eutypella canker of maples

Eutypella canker is widely distributed and there are local areas in the northern states where a considerable number of maples are diseased. It is caused by a fungus (Eutypella parasitica) which has black minute fruiting bodies sunken in the dead bark on the face of the canker (Fig. 3, A). It has targetlike concentric, flattened ridges which are wider than those of the Nectria cankers. Under the edges of the dead bark are white to buff fungus mats (Fig. 3, B). Infection usually appears to take place at the base of lateral branches although instances are known where infection entered a wound where a sprout had been removed. Sugar maple is most frequently attacked, but it has been found on red maple, box elder, and Norway maple. It apparently attacks while the trees are rather young but persists for years so that old trees are found with it.

Hypoxylon canker of maples

A canker of sugar and red maples caused by Hypoxylon blakei has recently been reported from Canada. A similar canker has been found in northern New York, Vermont, and New Hampshire. Only a few examples have been seen and until further observations are made no information is available as to the importance of the canker in stand improvement.

Hypoxylon cankers are elongated lesions on the trunk to which the bark adheres at least for the first season or so. This bark finally splits, exposing the wood which shows concentric ridges similar to Nectria cankers. Spore-producing bodies of the fungus are found at the upper or lower margins of the canker and burst through the bark as hard, black, cushion-shaped objects about an eighth to a quarter of an inch

across (Fig. 3, C). Diagnosis of a canker as Hypoxylon canker is dependent upon the presence of these spore-producing bodies.

Aspen black canker

Aspen black canker is caused by the fungus Hypoxylon pruinatum and results in considerable damage through breakage by heavy winds. It is usually located on the main trunk about half-way up on trees 20 years or more old. In the Northeast quaking aspen is much more susceptible than the other aspens, but in the Lake States they are reported as about equally susceptible. Black canker appears to be prevalent throughout the range of quaking aspen. The canker forms on smooth bark, first showing as slightly sunken, yellowish areas, often with exuding liquid at the edge. It rapidly spreads so that it usually is from 1 to 4 or 5 feet long and commonly extends around the trunk, completely girdling it. After a short time the epidermis breaks open and the black, fungus-permeated bark within is exposed. The wood within the blackened bark is weakened by the fungus and the tree breaks over at that point. The disease is most severe on poor sites.

Cankers associated with wood-rotting fungi

Certain wood-rotting fungi after becoming established in the wood of a living tree gradually kill the sapwood and cambium around the point of infection causing a more or less noticeable canker. As the rot spreads in the tree it often works outward through branch stubs and healed over branches, causing other cankers to develop on the trunk (Fig. 3, D). These rot cankers often have enlarged margins with prominent callus. Rot cankers as a rule have sterile fungus material deposited in the face of the canker which may form pronounced sterile conks. Rot cankers are unmistakeable evidence of decay and infected trees should not be selected for crop trees. The important fungi associated with rot cankers in northern hardwoods are: Daedalea unicolor, Polyporus glomeratus, Poria obliqua, Ustulina vulgaris and Fomes igniarius var. laevigatus. These are described under "Fungi causing rot in northern hardwoods."

WOOD ROTS

Wood, whether part of a living or dead tree or manufactured into lumber, is subject to attacks by various fungi resulting in rot or decay. Wood-rotting fungi are classified as (1) sapwood rotters if they attack only dead sapwood of living trees, and (2) heart-rotters if they specialize on the heartwood. Fungi that live on dead wood are sometimes called saprophytes. Heart-rotting fungi, by means of spores, infect trees through wounds of various kinds and the resulting rot is called (1) butt rot if confined to the butt of the tree, (2) trunk rot if in the middle trunk section, and (3) top rot if restricted to the top. Butt and trunk rots probably cause the greatest loss because they destroy the heartwood in the part of the tree having the greatest volume and highest commercial value.

Rots can be divided into two types, white and brown, depending upon the color of their advanced stages. White rots are usually soft and somewhat fibrous; brown rots are dry and powdery. The former are most frequent in northern hardwoods.

Wounds that expose heartwood are particularly suitable for infection by heart-rotting fungi, and the larger the wound the greater the decay hazard. Infections by heart-rotting fungi through exposed dead sapwood may take place but these are less likely because of competition from faster growing, more numerous sapwood-rotting fungi. Sapwood-rotting fungi that decay the dried-out sapwood of wounded areas are sometimes referred to as "wound saprophytes." Their activity is limited to the wound area and does not commonly extend for any distance into the heartwood. Wound saprophytes are believed to prevent heartrot in some instances by decaying the exposed sapwood and thus rendering the wound unfit for infection by true heart-rotting fungi.

The life history of a wood-rotting fungus is completed by formation of a spore-producing body commonly called a conk and more technically a fruiting body or sporophore. These are produced by some saprophytic species shortly after rot is established in the wood. Most species of heart-rotting fungi are present for many years and cause extensive rot before a fruiting body develops. Some commonly produce the sporophores on the living rot-infected tree, while others produce them only after the tree has been dead for a number of years; trees decayed by these latter fungi commonly bear rot cankers or sterile fungus masses on the trunk as evidence of infection.

Wood-rotting fungi are classified and named on the basis of the structure of their sporophores. The common shelf fungi found on living and dead trees belong for the most part to the polypores (Polyporaceae) or many-pored fungi, so named because the spores are produced in tiny tubular pores on the underside of the shelf. Many fungi belonging to two genera of shelf polypores, namely, Fomes and Polyporus are important as heart-rotters. Fungi belonging to the genus Fomes form hard, woody, perennial sporophores commonly called punks or conks. These are infallible signs of decay. Fungi belonging to the genus Polyporus form less durable sporophores that persist for only one season. These are generally produced each year and are often soft, fragile and quickly destroyed by insects. A third genus of the Polypores, Poria, includes the pore fungi that do not produce shelves but whose pore-bearing surface develops as flat mats on the surface of the wood or bark. A few mushroomlike fungi are associated with decay of living trees but the sporophores are very short-lived and are rarely encountered in stand improvement work. Certain fungi that form crustlike smooth surfaced fruiting bodies and those that form teeth or spines are also encountered but in general the most damaging heart-rotters are various forms of the polypores.

FUNGI CAUSING ROT IN NORTHERN HARDWOODS

In this section a brief description is given of some common fungi causing rot in northern hardwoods, dealing chiefly with those fungi which form conks with considerable frequency on rotted trees or produce other evidences of infection by which their presence can be recognized. Unfortunately the frequency with which fungi produce conks on infected trees is no indication of their importance as disease producers. Some of the important rot fungi form conks only occasionally on living infected trees and not until after the rot has been present for many years. These conks may be inconspicuous and short-lived and are frequently overlooked. Further investigations of rot in northern hardwoods, based on cultures of the causal fungi isolated from rotted wood, may reveal others that are more important than those already known. The fungi described here are not the only ones causing rot in northern hardwoods but rather are the ones that we know most about and whose presence we can ordinarily detect. Most fungi that form conks on living trees will continue to do so on felled trees left in the woods.

Pore fungi that form perennial conks on living trees

Fomes igniarius. Fomes igniarius causes a white trunk rot of most hardwoods with the exception of oak. In New England and northern New York conks of the fungus are common on beech, aspen, birch, ironwood, and maple, (Fig. 4, A). They occur infrequently on ash, basswood, and black cherry. In southern New York and Pennsylvania conks are found chiefly on ironwood and aspen and only occasionally on other species. Infection takes place mostly through wounds but may occur through dead stubs and dead companion sprouts.

Conks of F. igniarius are hoof-shaped or flattened with a brown pore surface and a black cracked or checked upper surface. They are perennial and increase in size each year by the addition of a fresh layer of tubes. The color of the interior is dark brown flecked with white. The tube layers are short and not distinct from each other. The size of the conks depend on their age and in time they may form shelves that project from 8 to 12 inches. The conks may occur singly on the trees or in groups of two or more. Occasionally these develop in sunken cankerlike areas on the trunk. Aborted or poorly formed conks which resemble sterile conks of Poria obliqua form on beech and birch. These may develop alone on the tree or associated with normal conks of F. igniarius.

Fomes applanatus. Fomes applanatus causes a mottled white rot in many hardwood species. The conks are common on dead standing trees or down logs but may develop on living trees especially beech and sugar maple (Fig. 4, B). Conks are common on street maples developing on wounds or in connection with large dead branch stubs. The presence of conks on living trees indicates extensive decay and street trees are usually

so weakened by the time these develop as to be in danger of windthrow. Infections in forest trees are confined chiefly to wounds and large dead branch stubs.

The conks are rarely hoof-shaped and are generally flat and project from the wood or bark as a thin or moderately thick shelf. These may persist for years and attain a large size. The upper surface has definite ridges denoting seasonal activity and is usually smooth, gray or brown and not cracked or checked as in F. igniarius. The under or pore side is white or yellowish when fresh but occasionally brown in old specimens. The white underside turns brown where rubbed and large conks are sometimes used for drawings which can be made with a sharp pointed stick. The interior is dark brown.

Fomes applanatus can be easily recognized as it is the only Fomes species with a white pore surface that has a dark brown interior.

Fomes pinicola. Fomes pinicola causes a brown cubical rot chiefly of conifers but it may also infect hardwoods. The conks usually develop on dead or nearly dead trees but are common on living, vigorous black cherry on the Allegheny Plateau. They may also develop on beech and birch. In hardwoods the fungus probably causes important top and trunk rot only in black cherry. In this species infections are mostly through large dead branches and trunk wounds.

The conks are somewhat flattened or occasionally hoof-shaped with a smooth, ridged upper surface. The ridges are caused by the formation of annual layers of tubes and are an indication of the age of the fungus. The older ridges become black, the youngest ridge is at first yellowish or pinkish and usually finally becomes definitely red with a varnished appearance. The common name, the "red belt fungus" is derived from the red margin of the conks. The pore surface is usually pinkish or yellowish. The interior is cream color or somewhat dirty yellowish and shows distinct tube layers. The texture is tough and rubbery. Like all Fomes species the conks vary considerably in size depending upon age.

The fungus is easy to recognize where well-developed by the pinkish or red margin of the conk and by the creamy interior.

Fomes connatus. Fomes connatus attacks a variety of hardwoods but is important only on sugar and red maples. The rot is white, soft, and watery, and usually the older infected wood breaks down completely, forming a hollow. The rot is generally limited and ordinarily does not extend more than a few feet above the conk.

Conks of F. connatus are small to medium but occasionally become very large (Fig. 4, C). When newly formed they are soft, white, and usually watery, but on drying become yellowish and corky. With age the upper surface becomes covered with green moss and this green covering provides an easy means of identifying the fungus. The conks are perennial and in section the annual tube layers are quite distinct.

Fomes connatus apparently forms a conk after only a small amount of decay has been caused. The conks persist for years and infected trees can ordinarily be easily recognized and should be discriminated against in stand improvement.

Fomes fraxinophilus. Fomes fraxinophilus causes a white or somewhat yellowish top and trunk rot in living American ash trees. Infection takes place through dead branches and the conks usually develop on the underside of dead branch stubs (Fig. 4, D). The conks are hoof-shaped or irregular in form and are black and much cracked and checked on the upper surface. The under or pore surface is white, yellowish, or light brown. The interior is firm, light brown or pale yellow, and usually the tube layers are not distinctly separated from each other. The fungus is ordinarily overlooked in the forest because it frequently produces its conks in the tops of infected trees.

Fomes fomentarius. Conks of Fomes fomentarius are found occasionally on living birch and maple associated with a white or yellowish trunk rot. Conks of F. fomentarius are typically hoof-shaped. The upper surface is gray or brown, smooth and shiny, with zone lines paralleling the margin. The underside is light gray or brown. The interior is brown and firm, and the tubes are often 2 or 3 inches long in large conks.

Daedalea unicolor. Daedalea unicolor belongs to a group of the polypores in which the pores are elongated and sinuous, and which in old specimens frequently split from each other, giving the undersurface of the conks a toothed appearance. The conks develop one above the other as a series of shelves that project from one to three inches from the bark and which are either independent of each other or are united at their bases (Fig. 5, C). The upper surface of the thin, tough, leathery conks is zoned, usually hirsute, and when young yellowish white or light brown. Older conks become greenish. The underside is usually ashy gray or occasionally dull lilac.

Daedalea unicolor causes a white rot chiefly of maple but may attack practically all hardwood species. It occurs also very commonly on dead logs and limbs in the forest. Infection of living trees takes place through wounds and branch stubs, and in sprouts through dead companion sprouts (Fig. 5, A and B). The rot travels faster in the older wood at the center of the tree than in the sapwood, and the sapwood is gradually killed around the infection point, causing a canker to develop. This keeps enlarging from year to year, resulting in elongated flattened callus ridges on the trunk. Ordinarily the fungus fruits on the canker soon after it develops and usually the conks completely cover the cankered area. The rot weakens the tree so that it is eventually broken over. This further stimulates conk formation and the broken tree continues to produce conks over nearly its entire length for several seasons. If a companion sprout in a clump is attacked by the fungus the others in the clump are doomed since the fungus can spread from one to the other by means of the sapwood connection at ground line.

Daedalea unicolor infections on sugar and red maples are common in New England and northern New York. Infected trees usually can be recognized by the conks which develop soon after a canker forms. Conk formation is less common on the diseased trees in Pennsylvania. In one area in Vermont and in another in northern New York the fungus was found infecting the stubs of sprouts cut in improvement work. Where the fungus is locally abundant the severance of stems in a sprout clump may be somewhat more hazardous than usual.

Pore fungi that produce sterile conks or cankers on living trees, and spore-producing bodies on these trees after they are dead.

Poria obliqua. Poria obliqua causes a white rot of birches indistinguishable from that caused by Fomes igniarius. Infection takes place through branch stubs, wounds, and old Nectria cankers. The rot is confined to the center of the tree and is most frequently found as a trunk rot but may also occur as a butt or top rot. Sterile, black, clinkerlike masses of fungus material commonly develop at the infection point and elsewhere on the trunk, depending upon the progress of the rot within the tree (Fig. 6, A and B). The fungus has been called Fomes nigricans or has been considered a sterile form of F. igniarius on the basis of these characteristic sterile conks.

The poria or spore-producing stage does not develop on the living infected tree. Rot-weakened stems ordinarily break at a point where a sterile conk has formed. The rot in the center of the tree works outward through the dead sapwood, and after the tree has been dead for several years the poria stage develops under the bark or under a thin sapwood layer causing the bark and wood to split open (Fig. 6, C). This exposes the brown poria which sheds pale yellow spores in great quantities. The poria fruiting body lasts only a short time and is soon destroyed by insects and weathering. The fruiting habit is such that ordinarily but few specimens of the poria stage can be found, even in birch stands with many sterile conks.

The sterile conks of P. obliqua have been observed most frequently in Vermont, New Hampshire, and Massachusetts, and in the Adirondack Mountains. They are less common in Pennsylvania. Sterile conks are also reported on birch from the Lake States. The disease is found on practically all the common species of birch and has also been noted on Eastern hophorn beam, Ostrya virginiana.

Polyporus glomeratus. Polyporus glomeratus causes an important soft, white or yellowish trunk rot of red maple, sugar maple, and beech. Infection takes place mainly through dead branch stubs and the resulting rot, once it is established in the center of the tree, may extend a considerable distance up and down the trunk. The diameter of the rot cylinder is often relatively small and confined to the older wood at the center of the stem. Infected branch stubs especially on red maple develop abnormal callus resulting in prominent, woody knobs (Fig. 7, A). These usually remain unhealed and have a hollow center which is more

or less plugged with sterile fungus material (Fig. 7, B). On infected beech these sterile fungus masses, that are dark brown or black and much cracked or checked on the surface, frequently become large, protrude noticeably from branch stubs, and resemble somewhat the sterile conks produced by Poria obliqua on birches. On maples these sterile masses are quite large at times but rarely protrude conspicuously.

With the extension of the rot within the tree additional swollen branch stubs may develop at various heights on the trunk, or cankers which frequently become large and much elongated are formed by the rot fungus killing the sapwood and cambium (Fig. 7, C). Such cankers often develop as sunken areas on the trunk bounded by faint to prominent callus ridges. The bark on these cankered areas generally remains firmly attached and is often permeated with sterile fungus material forming a thick crust which is black on the surface and brown and softer beneath. Badly rotted trees often become very much distorted from the swellings and cankers which develop at various heights on the trunk. Swollen branch stubs are not a positive indication of P. glomeratus on maples as these sometimes develop on disease-free trees. A definite diagnosis can be made by cutting into the center of the suspected swollen stub or canker. If the cut discloses a yellowish-brown, granular, fungus material which appears to contain small, black, gritty particles where exposed to the air and is spongy and softer deeper in the wound, the rot is caused by P. glomeratus. Such exploratory cuts should be made with caution so that excessive wounding may not result on sound trees.

The fungus material produced in branch stubs and cankers on living trees is entirely sterile and does not produce spores of any kind. Spore-producing conks do not form on the living trees. Rotted trees finally become weakened sufficiently to break off. The rot present in the center then progresses through the dead sapwood and after several years the trunk is thoroughly decayed. Spore-producing conks are produced in abundance on thoroughly decayed logs and consist of a series of fairly thick shelves which project from 2 to 4 inches from the wood (Fig. 7, D). These have a common base and usually grow on the sides and bottom of the log. The upper surface of the newly formed conks is brown and the under or pore side is much lighter, usually somewhat gray or a pale brown. In texture fresh conks are firm, tough, somewhat watery, and dark brown within, and when dry become hard and brittle. The spores which are produced in great abundance are bright greenish-yellow and often cover the tops of the conks, the ground, and surrounding objects for several yards with a greenish-yellow powder.

The conks remain in a fresh condition but a short time and soon become uniformly dark brown, sodden, and riddled by insects. Usually only a single mass of conks is produced by a rotted log but occasionally a second crop appears the following year. The amount of fruiting the second year is usually smaller than that produced the first. Although P. glomeratus rot is extremely common in maple, the conks of the fungus are rarely encountered. This is due to their short life, inconspicuous location, and to the fact that they are produced only after the tree has been dead for years.

Red maple is the common host for P. glomeratus in the Northeast. Scattered infected trees can be found in most stands and local areas of heavy infection have been noted in New Hampshire, Vermont, New York, Pennsylvania, and West Virginia. Sugar maple is the common host in the Lake States. In the Northeast the disease has been encountered only infrequently on sugar maple, and areas of heavy infection have been found only in the Adirondacks. Infected beech have been found over the entire area but were most abundant in Vermont and New Hampshire.

Fomes igniarius var. laevigatus. Conks of this fungus are common in the northern hardwood forests on dead trees and down logs of several hardwood species, but are most frequently found on birch. They may also develop on living trees. They usually grow flat on the wood or bark but may occasionally form well-developed shelves with a smooth or cracked blackish top. The pores are brown and very small. The fungus causes a trunk rot of living yellow birch which resembles that caused by Fomes igniarius or Poria obliqua. Infection is mostly through dead branch stubs or wounds.

Sunken cankers commonly develop on the trunk, first at the infection point and then elsewhere as the rot progresses within (Fig. 3, D). These cankers may become large and occasionally numerous on badly rotted trees. Most cankers are found on trees 18 to 30 inches in diameter, but they may develop on trees as small as 10 inches in diameter. The bark adheres to the canker face and becomes permeated with fungus material which finally completely obscures the bark. This fungus and bark layer may be a half inch or more in thickness and is black, hard, and much checked on the surface but brown and softer beneath. Badly rotted trees may persist for years in a stand and only occasionally does one break off at a rot-weakened spot.

Yellow birches rotted by F. igniarius var. laevigatus and bearing distinctive trunk cankers are most common in the Adirondacks, and in Vermont and New Hampshire, but have also been found in northern Pennsylvania.

Pore fungi that form annual conks on living trees.

Polyporus sulphureus. Polyporus sulphureus, commonly called the "sulphur fungus" causes a brown rot principally of oaks but may attack other hardwoods. It is frequent on black cherry and is occasionally found on birch, maple, ash, and other species. Infection takes place through wounds.

The conks are annual and develop on dead logs and stumps as well as living trees in summer or early fall as a cluster of rather large shelves with a common base (Fig. 3, A). The upper surface is pink or salmon color and the pore surface is sulphur yellow. The texture is firm, cheesy and moist when young, becoming chalky with age. The red or pink color gradually fades and old conks are chalky white. The conks are short-lived and are soon riddled by insects.

Tooth fungi that form conks on living trees

Hydnum septentrionale. The conks of Hydnum septentrionale form a white compact mass of several to many shelves which ordinarily develops near a trunk wound (Fig. 8, B). The upper surface of the shelves is white and somewhat matted, hairy, and the under surface is composed of slender teeth one-half inch to an inch long. The interior is white. Conks develop in late summer and fall and soon die and deteriorate.

Hydnum septentrionale causes a white trunk rot of hardwoods. It occurs frequently on roadside sugar maples in New England and in forest stands is generally found on large sugar maple and beech trees. Infection apparently takes place through large wounds.

Hydnum erinaceus. The conks of Hydnum erinaceus are commonly spherical masses, the sides and bottom of which are covered with pointed teeth or spines (Fig. 8, C). The conks are white when fresh but quickly turn creamy or yellowish. The interior is white and fleshy.

Hydnum erinaceus causes a white heart rot, chiefly in oaks, but it and a closely related Hydnum are commonly found fruiting on beech and other hardwoods. In beech the fungus is generally associated with a white rot that breaks down the wood and forms large hollows. Infection probably takes place through wounds.

Miscellaneous fungi that cause rot in living trees

Armillaria mellea. The fruiting bodies of Armillaria mellea, commonly called the "shoestring" fungus, are mushrooms which may appear singly or in clusters in the fall at the bases of dead trees and old stumps (Fig. 9, A). The top of the cap is sticky or slimy when young, dirty white or tan in color, and usually somewhat watersoaked in appearance. It is generally covered with fine black dots. The stem usually has a conspicuous ring just under the cap.

Armillaria mellea causes a soft, white, watery, root and butt rot of maple, beech, ash, birch, and other hardwoods. Infection probably occurs through dead roots and wounds, but may take place through seemingly uninjured roots. The fungus is present almost everywhere in the forest soil but apparently cannot attack healthy trees. Trees weakened by drought or crowding may be attacked and eventually killed. The exposed wood at the base of a sprout next to the parent stump is usually rotted to a limited extent by the fungus and under certain conditions the rot may become extensive enough to weaken the sprouts so that they may blow over. Recently killed trees have the "shoestrings" of the fungus growing thickly under the bark at the base (Fig. 9, B). Overmature beech and maple are often badly damaged and hollow at ground line and in the butt from the activities of the fungus. In such trees Armillaria rot may extend upward from 6 - 8 feet. The rot is probably not important in young or middle-aged stands.

Ustulina vulgaris. The fruiting bodies of Ustulina vulgaris develop

on the dead wood of infected wounds, on dead roots, and at times on the soil adjacent to dead roots or dead wood. These are inconspicuous, thin, black, carbonaceous crusts which may cover an area of several square inches (Fig. 8, D). They are usually more abundant on down logs of maple and beech decayed by Ustulina than on living infected trees.

Ustulina vulgaris causes a white butt and trunk rot chiefly of maple and beech, but other hardwood species are occasionally attacked. The rot is distinctive and is characterized by numerous irregular black lines which form in the rotted wood. Infection takes place most frequently through wounds and dead roots but the fungus is sometimes transmitted from contact with diseased wood or roots. Sprouts originating on Ustulina-decayed maple stumps are attacked and rotted by the fungus. Sprouts are also commonly infected through dead companion stubs. Rot originating in the butt of the tree tends to spread radially to a greater extent in the root collar at ground line than upwards in the trunk. Maple and beech that are extensively decayed at ground line are often windthrown.

BURLS

The term "burl" is applied to large abnormal swellings on the trunk or main branches of trees. They vary greatly in size and shape and may involve the whole diameter of the stem at the affected spot, or only a portion of the diameter resulting in a swollen outgrowth. Burls occur on practically all hardwoods. Some are thought to be caused by bacteria and one on oak is definitely known to be associated with a fungus. Trees with burls should be discriminated against in stand improvement.

Fusiform burls are common on sugar maple on the Allegheny National Forest, Pennsylvania, and throughout the Northeast. The burls start as a localized swelling on which no injury is apparent and gradually increase in size. These usually develop cankerous areas which may heal partially and then break out elsewhere on the burl. The wood inside is greenish black compared to the white sapwood of maple and usually there is but a narrow band of unaffected wood outside the dark colored center. Wherever the greenish interior stain touches the cambium a canker develops. The cause of these burls is not known.

DISCOLORATIONS IN MAPLE AND BIRCH

Sugar maple is subject to greenish and black discolorations apparently originating at wounds or at old branch stubs. The discoloration is supposed to be due to some chemical reaction and limited greenish streaks in the sapwood are commonly called "mineral stain." A blackish discoloration of the central core of older trees is called "blackheart" (Fig. 9, C). Greenish discolorations are associated with both open and healed Nectria cankers, insect injuries, increment borings, and in fact all types of injuries exposing the wood (Fig. 9, D).

Since the value of sugar maple depends largely upon the white sapwood, these discolorations are of considerable economic importance. There

appears to be no means of control other than the prevention of wounds on the trunk.

Paper and yellow birches are subject to "red heart," a discoloration of the central core commonly associated with the fungus _Torula ligniperda_. Since paper birch is used for purposes in which white wood is the valuable part, the presence of red heart in any quantity causes considerable loss. No information is available on control.

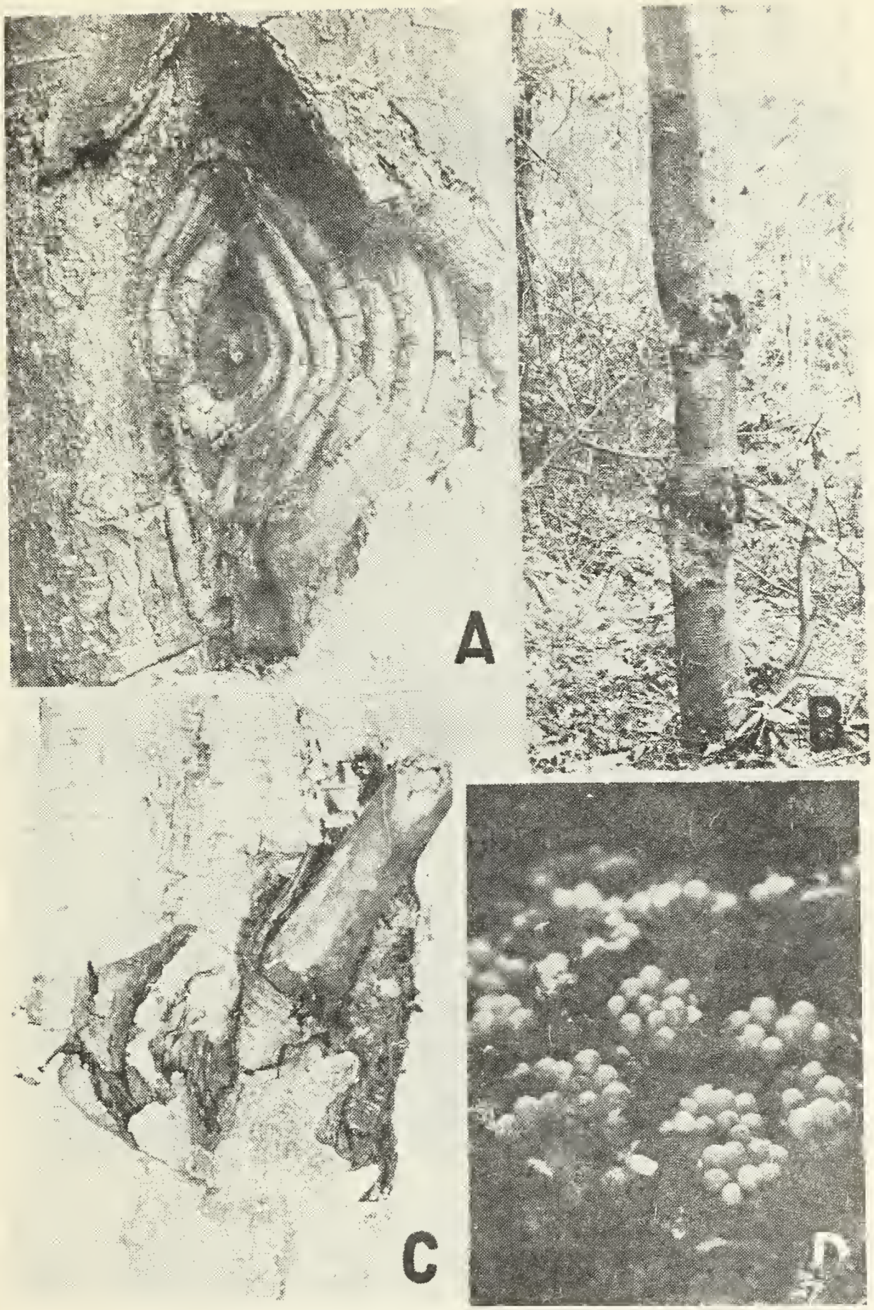

Figure 2. Nectria Canker

A. Target canker on sweet birch.
B. Open cankers on sweet birch, showing distortion of the stem.
C. Bark-covered canker on paper birch.
D. Fruiting bodies of Nectria enlarged approximately 15 times. These develop on the outer edges of the dead bark or on the wood next to the callus.

Photo by J. S. Boyce

Figure 3. Miscellaneous Cankers

A. Eutypella canker on sugar maple.
B. Buff-colored mycelial fans formed under the bark of canker A. Eutypella canker can be identified by these fans.
C. Hypoxylon blakei fruiting bodies on canker of red maple.
D. Canker associated with rot of yellow birch, caused by Fomes igniarius var. laevigatus.

Figure 4. Conks of Some Heart-Rotting Fungi

A. _Fomes igniarius_ conk on sugar maple.
B. Several conks of _Fomes applanatus_ on a broken over sugar maple.
C. _Fomes connatus_ conks on red maple.
D. _Fomes fraxinophilus_ conk on American ash.

Figure 5. Daedalea Unicolor

A. Canker of sugar maple originating around a small dead companion sprout.
B. Canker of sugar maple originating around a dead branch stub.
C. Conks of *D. unicolor* on sugar maple.

Figure 6. Poria Obliqua

A. Sterile clinkerlike conk on yellow birch.
B. Large sterile conks on paper birch.
C. Poria stage fruiting on a gray birch snag. The Poria developed under the bark which it split open permitting the spores to escape.

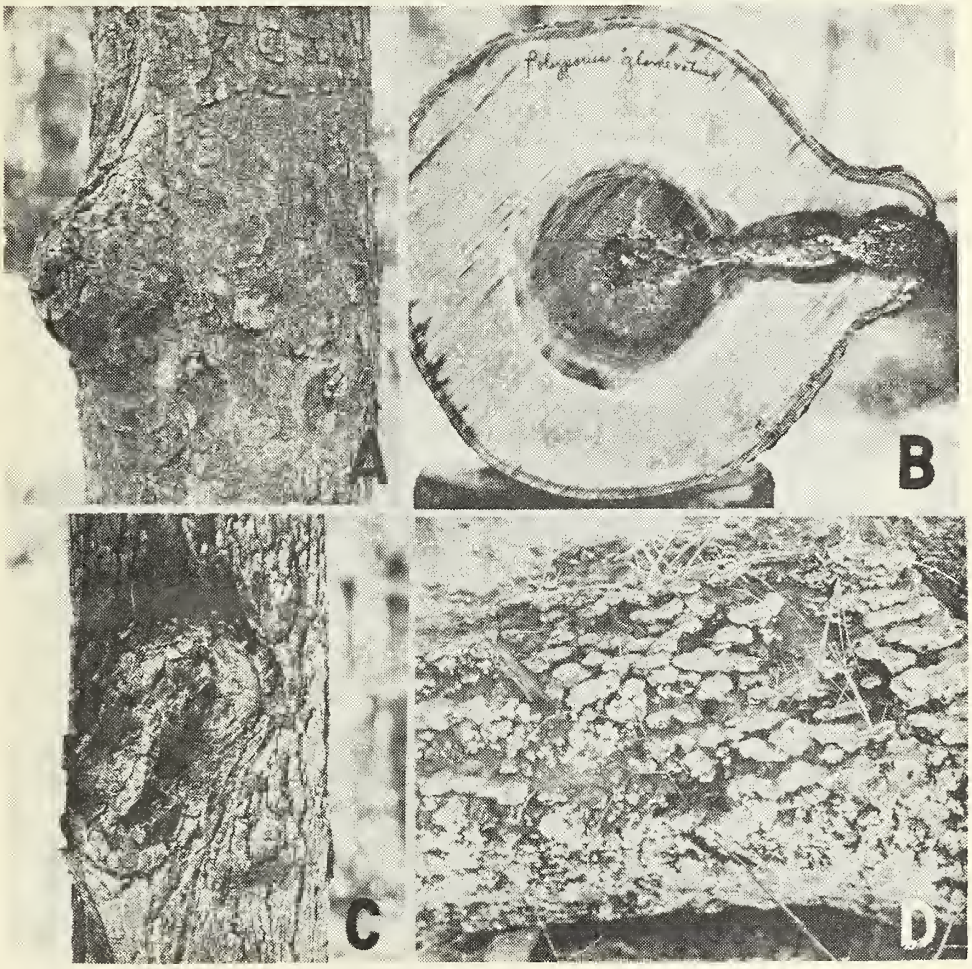

Figure 7. Polyporus glomeratus

A. Swollen branch knob on red maple.
B. Cross-section through A, showing rot and mycelial plug.
C. Canker on red maple.
D. Conks of P. glomeratus on old beech log.

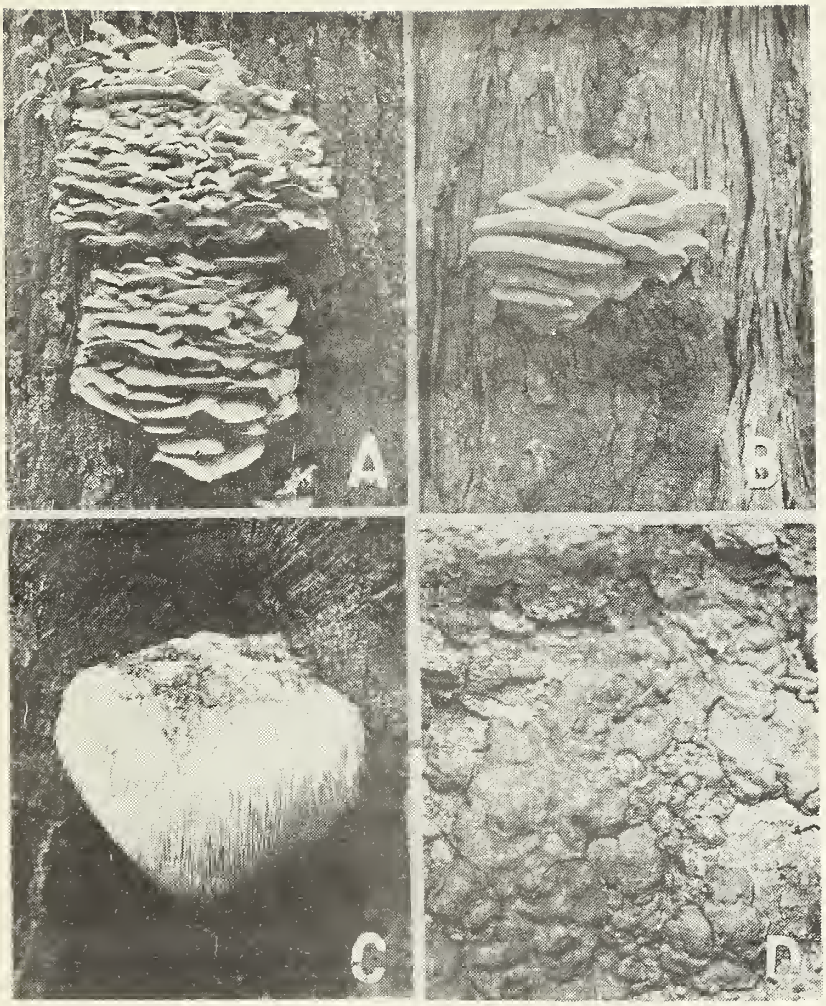

Figure 8. Conks of Wood-Rotting Fungi

A. Polyporus sulphureus on living oak.
B. Hydnum septentrionale on living sugar maple.
C. Hydnum erinaceus on wound in oak.
D. Crustlike fruiting bodies of Ustulina vulgaris on living beech.

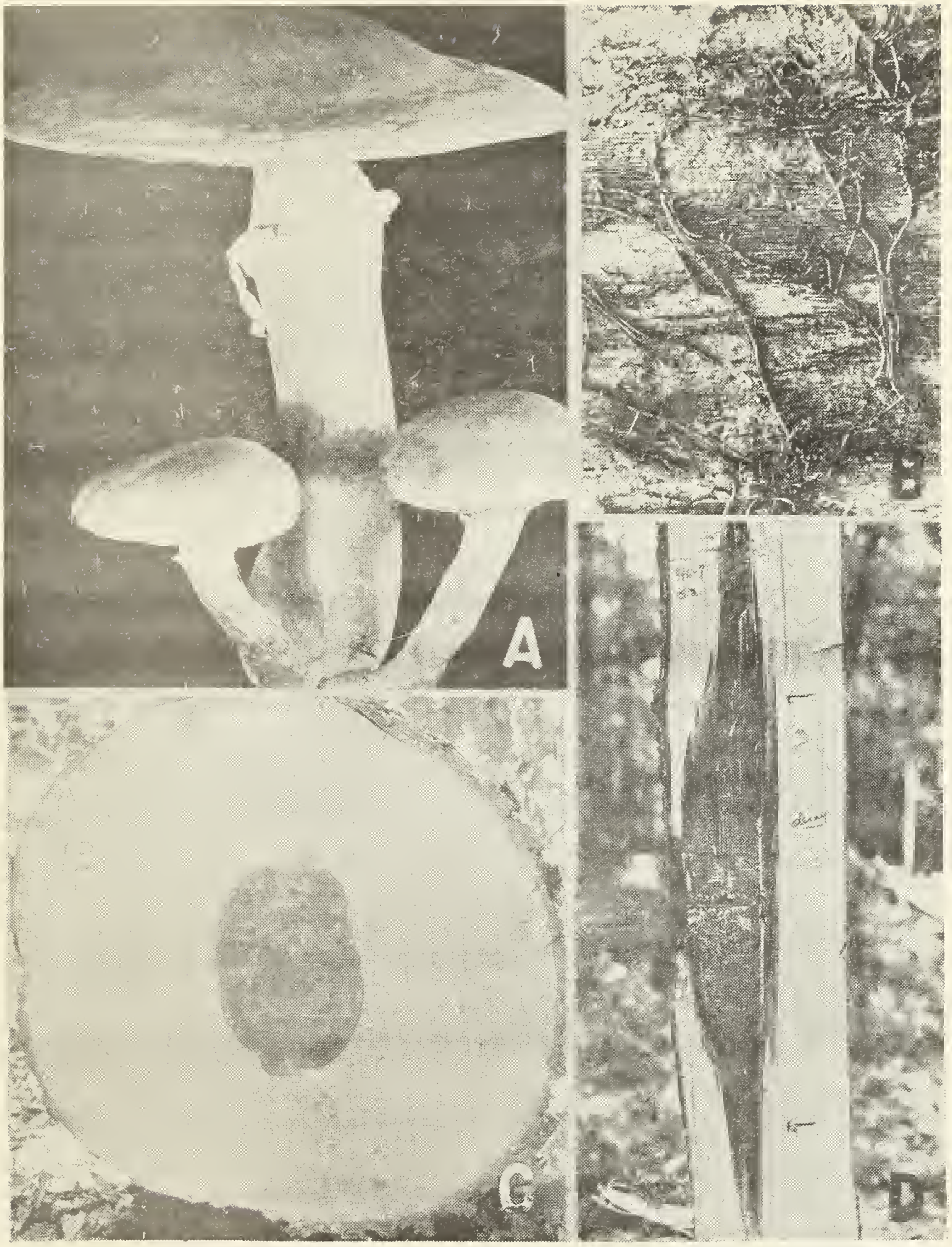

Figure 9. Armillaria Mellea and Discolorations of Wood of Living Trees

A. Fruiting bodies which develop at the base of infected trees.

B. "Shoestrings" which develop under the bark of infected trees.

C. A sugar maple 30 inches in diameter with a central core of "black heart".

D. Discoloration in sugar maple originating at an increment borer hole.

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David W. Robinson	Executive Secretary, Interstate Commission on the Delaware River Basin, Philadelphia, Pa
M. B. Saul	Counsel, The Morris Foundation, Morris Arboretum, Philadelphia, Pa.
George L. Schuster	Director, Agricultural Experiment Station, Newark, Delaware
J. Spencer Smith	President, New Jersey Board of Commerce and Navigation, Tenafly, New Jersey
W. S. Taber	State Forester, Dover, Delaware
Ezra B. Whitman	Engineer, Whitman, Requardt and Smith, Baltimore, Maryland
C. P. Wilber	State Forester, Department of Conservation and Development, Trenton, N. J.
Abel Wolman	Professor Sanitary Engineering, Johns Hopkins University, Baltimore, Md.

Hardy L. Shirley, <u>Secretary</u>	Director, Allegheny Forest Experiment Station, Philadelphia, Pa.